Design of a Passive RFID Tag Antenna at 2.45 GHz for Mounting on Various Platforms

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Abstract: **This paper presents the design of a passive RFID tag antenna operating at 2.45 GHz. The electromagnetic simulation software called CST is used for design and simulation. A high gain (5.842dB), a good impedance matching with the microchip (-30.0 dB Return Loss) and a satisfactory read range performance (upto 5 m) was obtained. One approach of designing RFID tag is that the tag should be less sensitive to the various types of objects. The effects of obstacles on antenna's characteristics have been investigated by placing the tag antenna against a metallic, rubber, glass and wood surfaces. Simulation results show slight variations which is within tolerance range.**

Key words: RFID, Tag Antenna, CST

I. Introduction

Radio frequency identification (RFID) system composes of a tag, which is attached to an object and uses an antenna to communicate with a reader [1]. There are several possible antenna types which can be used for RFID tags. The dipole types of antennas such as folded dipoles and meandered dipoles are used in many applications [2]. However, when they are mounted on the metallic objects, the antenna performance is degraded because of the variation of antenna impedance. The Microwave band RFID system is a passive system where a tag does not contain its own power source. Therefore, the reader antenna sends a radio signal into the air to activate the tag, then listens for a backscatter from the tag by powering it first,[4] and reads to accept the data transmitted by the tag. Passive tag antenna must be designed to transmit maximum power to the microchip without possible losses. Hence, near perfect impedance matching is required between the tag antenna and the microchip. Designing a passive tag antenna matched with the complex microchip impedance is the most challenging factor in this work, since a microchip has its small resistance and large capacitive reactance. Also, the impedance of an RFID tag antenna varies when it is mounted on different objects. Particularly, metallic objects strongly affect the antenna performance by lowering the tag's efficiency [7]. Hence, tag antennas have to be designed to enable tags to be read near and on metallic objects without performance degradation. In order to obtain stable antenna performance on various metallic platforms, minimizing the effect of the metallic supporting object is an important work. In this paper, Microwave tag antennas which are mountable on different object are introduced and analyzed.

II. Microwave-band Antenna Design

The tag antenna presented in this paper in a way that it utilizes the electromagnetic fields present near object such as rubber and metallic surfaces in order for the tag to be able to operate well when attached to the various types of objects. While that is one approach to design RFID tag to be less sensitive to the various types of objects, a common method frequently employed is the use of a microstrip patch antenna as the tag antenna[6]. The RFID tag consists of an antenna integrated with a microchip. For an impedance matching between the antenna and the RFID tag chip, a perfect match, and hence maximum power transfer occurs when the antenna impedance is the conjugate to the tag chip impedance. For the tag design here, the impedance matching method used utilizes a combination of via, steps cutting and a microstrip line feed with an inset into the patch radiating plate (Table 3.1). An illustration of the tag consisting of a rectangular patch antenna with an inset microstrip line feed is as shown in Figure 3.1.

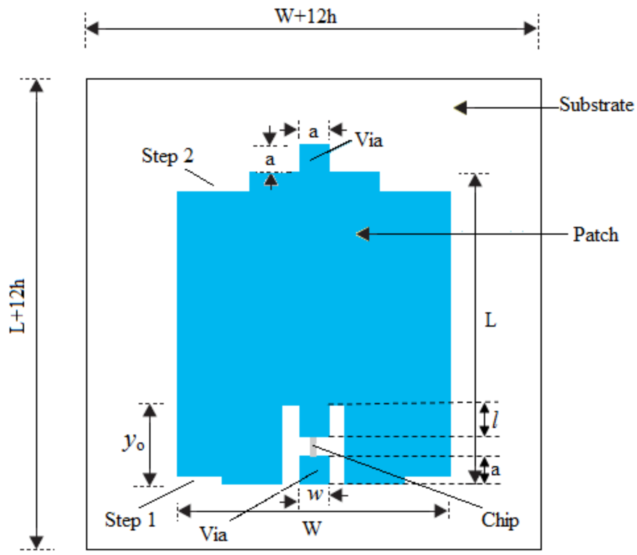


Fig.1: Structure of the RFID tag antenna

Table.1: Geometrical and dielectric parameters of the antenna structure

Patch Length, L	33 mm
Patch Width, W	31 mm
Substrate thickness, h	1.60 mm
Inset Depth, y_0	9 mm
Strip Width, w	3 mm
Length, a	3 mm
Length, l	4 mm
Step1, $l1$ x w1	1 mm x 7.5 mm
Step2, $l2$ x w2	2mm x 10.5 mm

III. SIMULATION OF ANTENNA

Designing a passive tag antenna matched with the complex microchip impedance is the most challenging factor in this work, since a microchip has its small resistance and large capacitive reactance. In this design the overall matching network is designed to conjugate match an RFID chip with a high capacitive impedance of 3.7- j60.02 Ω. The simulated input impedances of the antenna in the interested band are illustrated in Figure 2. At 2.45GHz, a simulated input impedance of 4.26+j60.33Ω is achieved, resulting in a -30dB return loss at that frequency. Figure 3 shows the simulated return loss and radiation efficiency.A directivity of 6.393 dBi is achieved with 88% radiation efficiency. An important performance criterion for RFID tag is its reading range the maximum distance at which tag can be detected

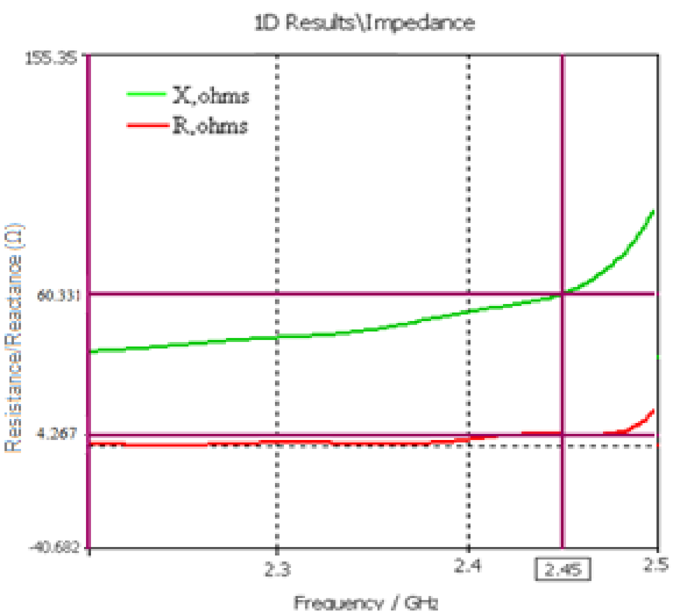


Fig.2: Simulated impedance plots of patch antenna

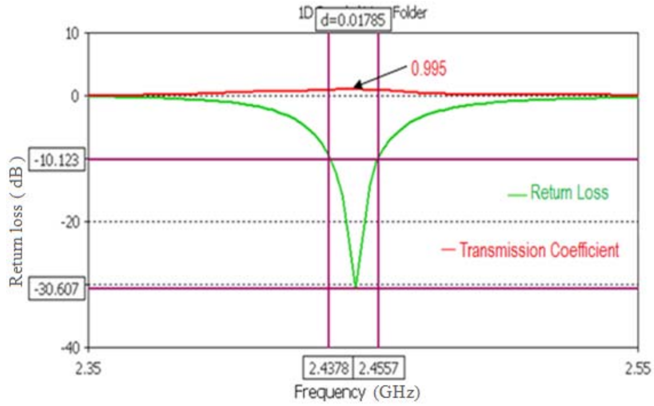


Fig.3. Simulated return loss and transmission coefficient.

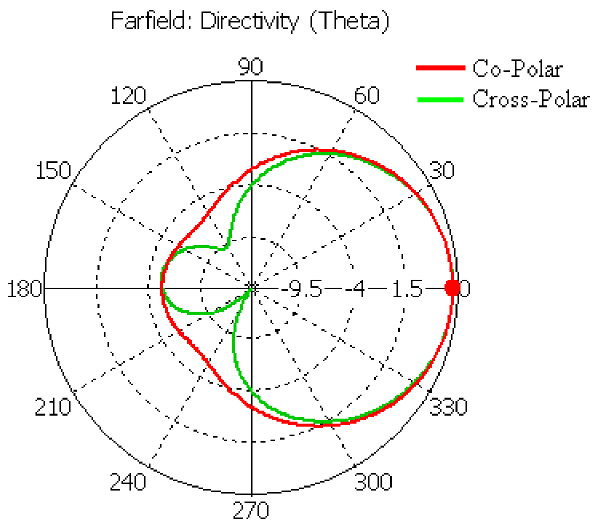


Fig. 4: Simulated far-field radiation patterns at 2.45 GHz for proposed antenna

IV. SIMULATION AND ANALYSIS OF ANTENNA MOUNTING ON VARIOUS PLATFORMS

The direction of the fringing field of a Patch antenna is always from the radiating element to the ground plane, and vice versa. Although this type of an antenna has its own ground plane, its performance will be affected when attached to the metallic platform. To make up for this drawback, the modified microstrip patch antenna as shown in Figure 5 is proposed. The proposed tag antenna consists of two vias shorted radiating elements, step cutting and a microstrip line feed with an inset into the patch radiating plate. The radiating elements are electrically shorted to the ground plane through the vias. The microstip line feeding, this is connected to the microchip. The conjugate match is achieved between antenna and microchip by adjusting the distance of the inset and the gap between the microstrip line and via shorting the ground. Then, the proposed tag antenna gives a smaller variation of the antenna performance than that of conventional tag antennas when the tag is mounted on the various sizes of the metallic platforms.

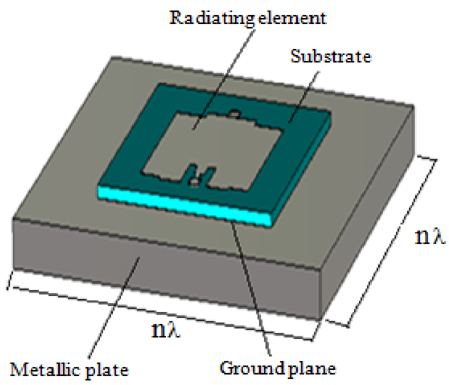
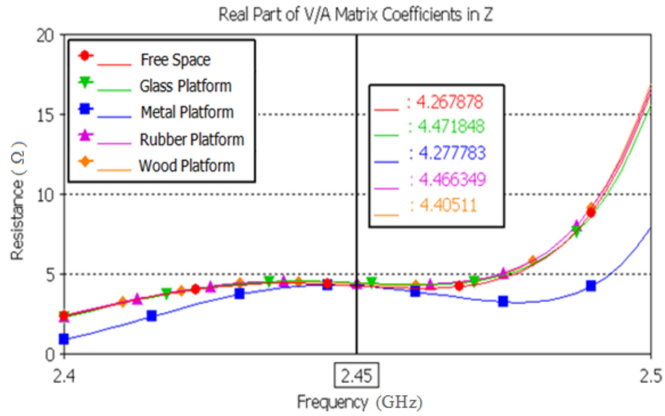
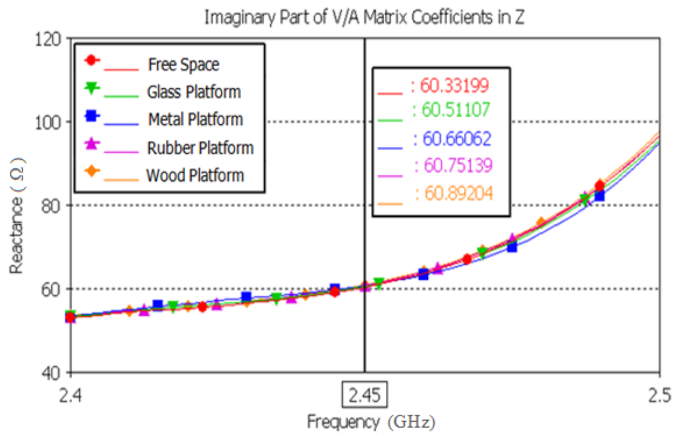


Fig. 5: Structure of the microstrip patches for Microwave tag antennas

The tag antenna structure is then simulated on a 1.5λ by 1.5λ various type of dielectric platform. The simulation results showed that the impedance remains almost the same as the case where the antenna is in free space. Hence, the impedance plot corresponding to having the antenna on a metallic plane is slightly higher amplitude than a free space and the other dielectrics (wood, rubber, glass) shown in Figure 6. However, the antenna gain is found to be slightly different from that of the antenna in free space and antenna on a metallic plane cases. Figure 7 shows the gain versus frequency for sizes of 1.5λ x 1.5λ various type of objects. The simulation gave an antenna directivity and gain of 6.346dB and 6.398dB respectively at 2.45GHz. The metallic object that the tag is attached to contributes to enhancement of the tag antenna gain by eliminating backward radiations. There is a little drop in antenna gain when the tag is mounted on various dielectric objects. The detailed data on the various types of object effect on the tag antenna and reading distance at 2.45GHz are summarized in Table 2. Figure 8 shows the return loss of tag mounted on various platforms at 2.45GHz. A tag is found less sensitive to the various types of object. This is because a patch antenna has a ground plane as part of the antenna itself, hence making a tag containing a patch antenna is less influence to the effects caused by placing that tag against a metallic, rubber, glass and wood surface. Figure 9 shows the radiation patterns of co-polarization and cross polarization. It is shown that the direction of the antenna main beam does not vary with the different platform, but its side lobe is distorted on metallic platform. It is noticed that the direction of the antenna's main beam does not vary with the size of the metallic platform. As can be seen, with the presence of a large metallic plane, the antenna pattern has smaller back lobe and the main lobe is fuller at the sides as compared to the free space case.



(a) Resistance



(b) Reactance

Fig. 6: Simulated Impedance characteristics with 1.5λ x 1.5λ of various platforms

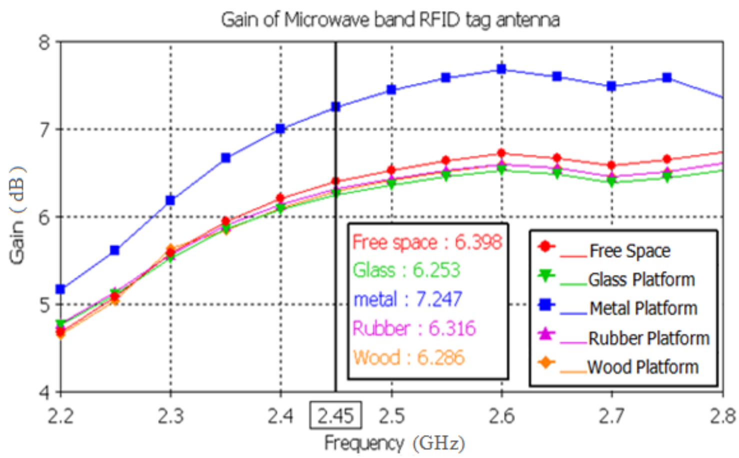


Fig. 7: Simulated gain for different sizes of various platforms

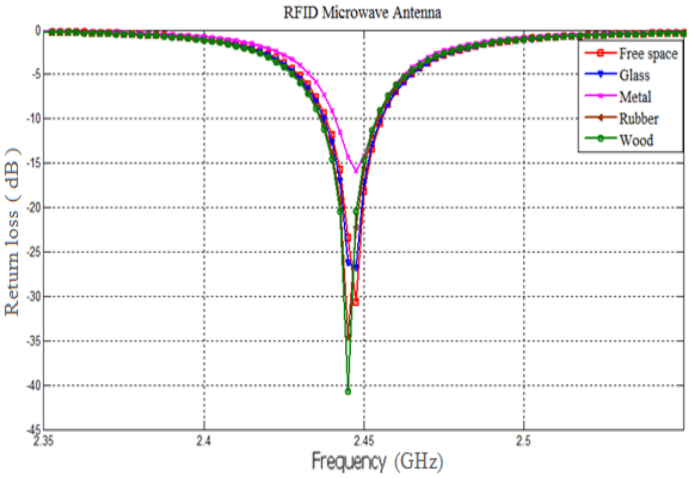
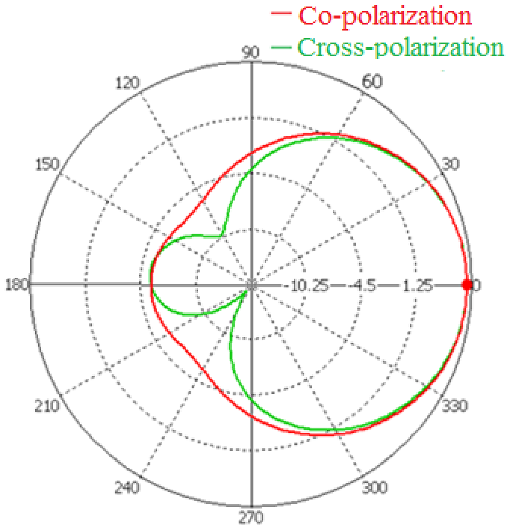
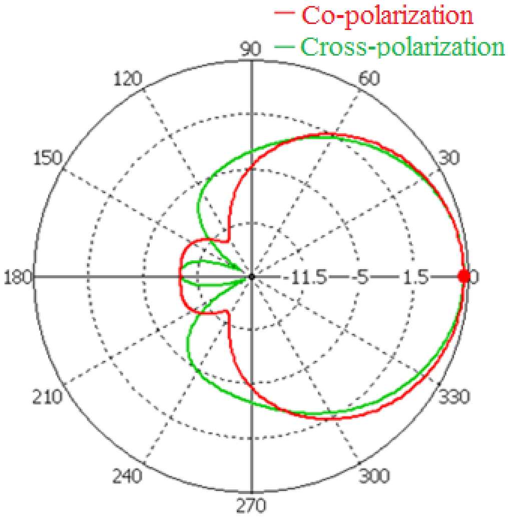


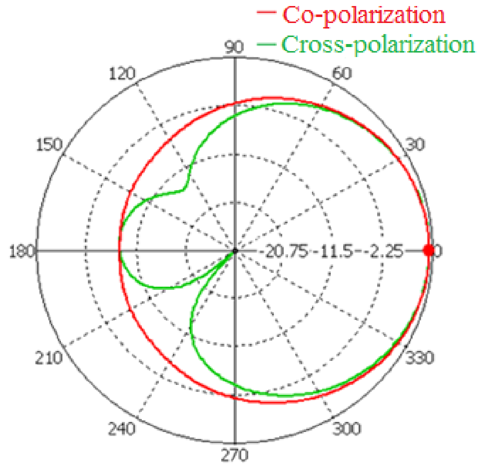
Fig. 8: Simulated Return loss for different sizes of various platforms



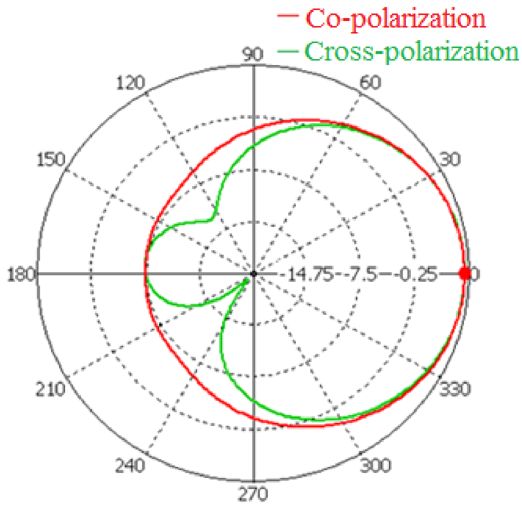
(a) Free space



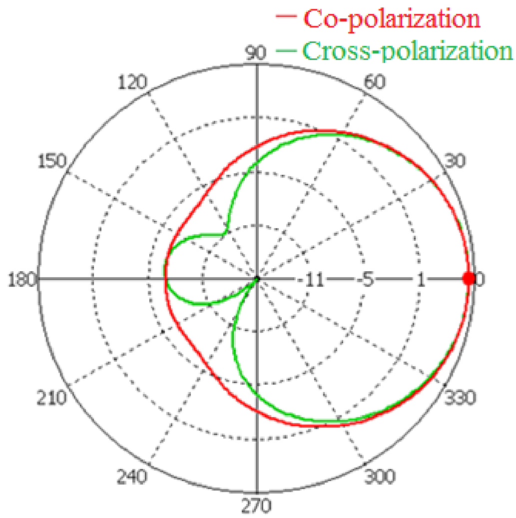
(b) 1.5λ x 1.5λ of Metallic platform



(c) 1.5λ x 1.5λ of Glass platform



(d) 1.5λ x 1.5λ of Wood platform



(e) 1.5λ x 1.5λ of Rubber platform

Fig.9. Simulated radiation patterns of various platforms

Table.2: Effect of various objects on the tag at 2.45 GHz.

	Gain (dB)	Input impedance (Ω)	τ	Reading Range (m)
Free Space	6.398	4.26+60.33i	0.995	3.823* 5.406
Foam	6.397	4.26+60.33i	0.995	3.822* 5.406
Metal	7.247	4.17+60.17i	0.996	4.217* 5.964
Glass	6.253	4.31+60.15i	0.994	3.758* 5.314
Wood	6.316	4.27+60.28i	0.995	3.787* 5.336
Rubber	6.286	4.29+60.26i	0.995	3.774* 5.337

*- circular-to-linear polarization mismatch

IV. CONCLUSIONS

In this paper, a microstrip patch antenna for Microwave–Band Passive RFID Tag has been designed. The proposed antenna consist of rectangular radiating patch with four steps, two vias and a microstrip line feed with an inset into the patch radiating plate . The simulation results show that a high gain, a good impedance matching with the microchip and a satisfactory read range performance was obtained. The effects of obstacles on antenna's characteristics has been investigated by placing the tag antenna against a metallic, rubber, glass and wood surface. Simulation results show slight variations which is within tolerance range and an intuitive perspective on fundamental requirements of antennas.

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